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Prediction of Thiamine and Ascorbic Acid Stability in Stored Canned Foods[a]

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The authors present nomographs which relate temperature, storage time and vitamin retention. These graphs permit prediction of retention values beyond the conditions of the actual experiments, by extrapolation. The results of other workers are compared favorably with the predicted values.

Introduction

Early studies in this laboratory have indicated that the loss of thiamine and ascorbic acid from miscellaneous food materials stored at constant temperature took the course of a first-order reaction *(7)*. Storage studies on representative canned foods used by the Army (apricots, orange juice, tomato juice, peas, spinach, green beans, and lima beans) were therefore conducted at three temperatures, 70°, 90°, 100° F. (21°, 32°, 38° C.) *(1)*, the minimum necessary to reveal if the classical Arrhenius equation was applicable. This was found to be the case. As a close approximation the logarithm of the retention and therefore the log of the storage life to a given retention were linearly related to the temperature (Figure 2). These simple relationships prompted an exploration of these storage data to determine if they could be used as a basis for (a) predicting stability of the two labile nutrients at storage temperatures and times outside the range originally studied, including variable temperatures; (b) estimating the limits of temperature and time at or below which a given retention (or better) of the nutrient in question may be obtained, and (c) predicting stability of these nutrients in foods similar to those employed in the original study.

This paper presents the temperature relationships found for the foods listed above in the form of nomographs. Their applicability to prediction are shown by comparing results of other workers at other temperatures with values predicted from these relationships.

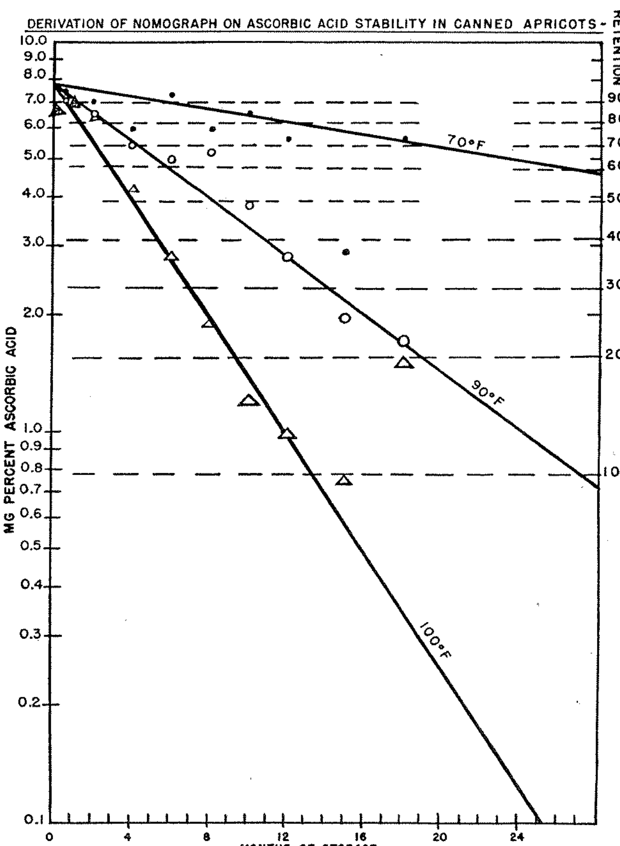

Fig. 1.

● — 70° F. ○ — 90° F. △ — 100° F.

Experimental Procedure

The experimentally determined vitamin values (mg. percent) were plotted on semi-logarithmic paper for each food against the months of storage for the three storage temperatures. The best possible straight lines

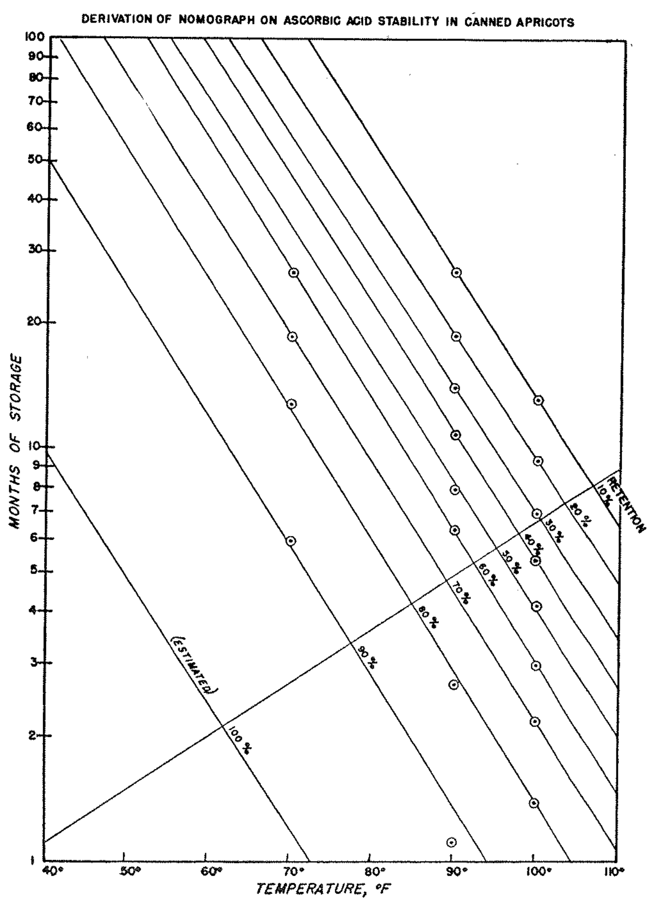

Fig. 2.

[a] This paper reports research undertaken by the Quartermaster Food and Container Institute for the Armed Forces, and has been assigned number 221 in the series of papers approved for publication. The views or conclusions contained in this report are those of the authors. They are not to be construed as necessarily reflecting the views or indorsement of the Department of the Army.

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representing the change in vitamin content during storage at each temperature were then drawn to meet at a common point on the mg. percent axis at zero months. This point was used as the initial vitamin value for each food.[c] Horizontal lines were then drawn across the graph at points which represented calculated retentions of 90% down to 10%, 10% intervals being employed. (See Figure 1). The intersections of these horizontal retention lines with the three constant temperature lines, enables one to read off the time in months which is required to bring about the given retention of the vitamin in question at the temperature indicated. To illustrate: the 80% retention line crosses the 70° F. (21° C.) line of ascorbic acid in apricots at 12.5 months, the 90° F. (32° C.) line at 2.7 months, and the 100° F. (38° C.) line at 1.4 months. Therefore, apricots retain 80% of their ascorbic acid for 12.5 months at 70° F., 2.7 months at 90° and 1.4 months at 100° F.

When log months were plotted against the temperature in degrees F. for each percent retention, a family of parallel straight lines was obtained. The family of parallel lines could be represented by their common perpendicular, it being necessary only to graduate the perpendicular to show where each line crossed. (Figure 2). Since the distances between these lines were logarithmically related it was possible to extend the graduations in both directions wherever necessary [d] by fitting a logarithmic scale to coincide with those graduations which had been experimentally determined. A nomograph [e] was then constructed from the data in Figure 2. This procedure was followed for both thiamine and ascorbic acid for each food studied by Brenner et al *(1)*. (See Figures 3 and 4).

Results and Discussion

To determine whether such nomographs can predict results obtained by other investigators for these foods stored at different temperatures, the data in Table 1 have been gathered from the literature and compared to values obtained from the nomograph. The results show good agreement between experimental and predicted values. It is obvious that these nomographs cannot be expected to give fully accurate results in the extremities of the temperature range if only because water freezes at 32° F. (0° C.) and browning increases rapidly at the higher temperatures. Furthermore, sam-

[c] This procedure was followed since the original analyses were just as much subject to error and sample variability as any others.

[d] The limited scale in Figure 1 (0-28 months) made it impractical to estimate the lower retention values directly for the more stable foods, and therefore, extrapolation was necessary in Figure 2. In every case 100% retention was determined in this way.

[e] The procedure for constructing the nomographs was as follows: A logarithmic (1 — 100 months) and a parallel linear scale 0 — 140° F. (— 18 — 60° C.) were marked off. Two well separated points were chosen from each constant retention line of Figure 2. Working lines were then drawn joining the readings on the scales representing the storage time and temperature of these two points for each constant retention. The intersection of these two lines represented the constant retention characteristic of the two points which were used.

For example, the intesection of the 100 months, 55° F. (13° C.) temperature working line with that of the 2.0 months, 110° F. (43.5° C.) temperature line represented the 50% constant retention point on the third scale being constructed. This same procedure was used to extend the scale at 10% intervals from 10 to 100% retention.

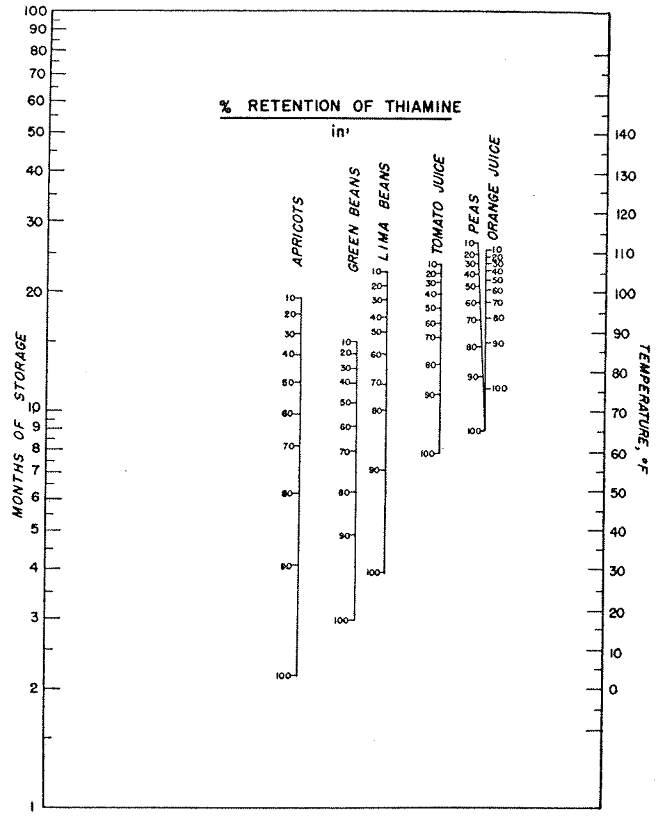

FIG. 3. Nomograph for stability characteristics of thiamine in canned foods.

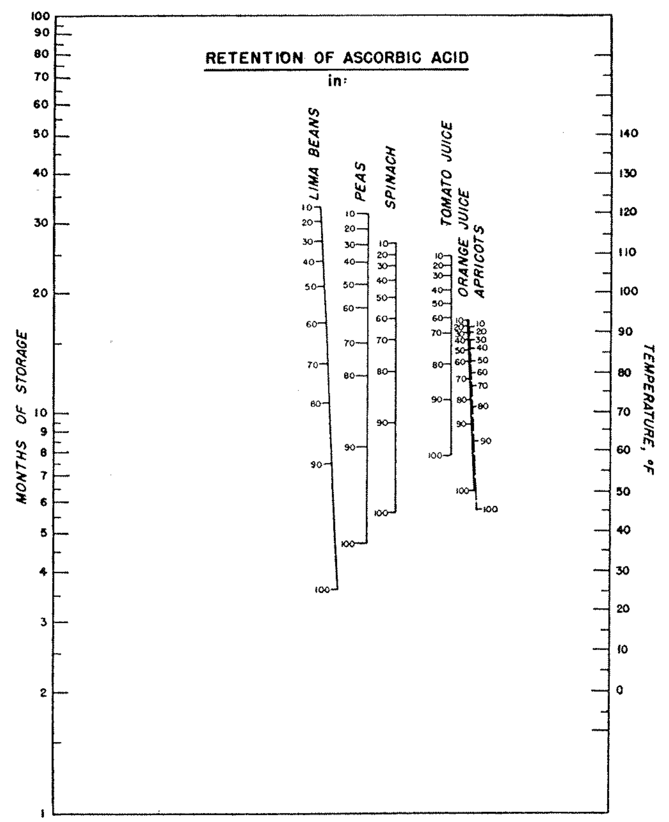

FIG. 4. Nomograph for stability characteristics of ascorbic acid in canned foods.

TABLE 1

Comparison of Predicted Storage Retention of Ascorbic Acid and Thiamine With Experimental Values Obtained by Various Workers

Product	Storage Temperature ° F.	Ascorbic Acid 6 mos. Stor. Percent Ret. Found	Ascorbic Acid 6 mos. Stor. Percent Ret. Pred.	Ascorbic Acid 12 mos. Stor. Percent Ret. Found	Ascorbic Acid 12 mos. Stor. Percent Ret. Pred.	Thiamine 6 mos. Stor. Percent Ret. Found	Thiamine 6 mos. Stor. Percent Ret. Pred.	Thiamine 12 mos. Stor. Percent Ret. Found	Thiamine 12 mos. Stor. Percent Ret. Pred.
Tomato Juice *(2)*[f]	70	86	97	83	91	......	......	......	......
(3)[g]	30	100	100	92	100	100	100	92	100
	42	98	100	90	100	98	100	90	100
	85	90	90	74	79	89	89	71	79
	110	50	63	20	40	50	60	18	34
(6)[g]	50	92	100	100	98	100	100	95	100
	65	95	94	96	93	98	100	92	94
	80	98	93	86	84	92	92	84	84
Orange Juice *(6)*[g]	50	100	100	97	95	100	100	100	100
	65	96	97	92	90	98	100	98	100
	80	88	84	76	68	94	100	86	98
(5)	70	91	92	87	82	......	......	......	......
Peas *(2)*[f]	36	99	99	98	94	......	......	......	......
	70	87	90	84	83	......	......	......	......
	90	81	84	76	74	......	......	......	......
Spinach *(2)*[f]	70	82	84	76	83	......	......	......	......
Lima Beans *(3)*[g]	30	94	96	......	......	100	96	100	94
	42	84	94	......	......	96	94	96	91
	85	70	84	......	......	86	85	77	72
	110	60	74	......	......	41	57	22	32

[f] These values represent average retentions for food packed in glass containers and stored in the dark at the temperatures designated.
[g] Values estimated from published curves.

ple variation is considerable even in the relatively homogenous material from which these nomographs were derived *(1)*. Different experimenters, interseasonal, varietal and geographical differences in the food, variations in processing, etc., may all introduce differences of a completely uncontrollable character.

The data in Table 2 show the applicability of these nomographs for predicting storage stability under variable temperature conditions such as occurs in warehouse storage. It is clear from Table 2 that using yearly average temperatures, it is possible to predict within experimental error the vitamin retention for the foods enumerated. Moschette, Hinman, and Halliday *(6)*, Brenner, Wodicka, and Dunlop *(1)* have previously indicated this to be the case, by comparison of results of warehouse storage with data obtained at constant temperatures in the proximity of the average yearly temperature.

TABLE 2

Prediction of Ascorbic Acid and Thiamine Retention From Annual Average Temperature in Warehouse Storage

	Storage Temp. Yearly Av. ° F.	Storage Temp. Yearly Range ° F.	Retention of Ascorbic Acid Percent Found	Retention of Ascorbic Acid Percent Pred.	Retention of Thiamin Percent Found	Retention of Thiamin Percent Pred.
Orange Juice *(6)*	77	50- 98	73	72	96	98
	77	54- 91	81	72	95	98
	72	50- 92	81	79	99	100
	70	54-104	86	82	99	100
	66	51- 87	92	86	96	100
	63	42- 79	91	90	103	100
	61	36- 87	91	91	95	100
	59	28- 92	90	93	99	100
	58	30- 78	96	92	98	100
Orange Juice *(1)*[h]	77		75	72	72	98
Spinach *(1)*[h]	77		83	82	....	....
Peas *(1)*[h]	77		86	81	80	91

[h] Storage studies in same Florida warehouse used in *(6)*; average annual temperature assumed to be the same.

From these nomographs it was interesting to estimate the storage temperature at which a change in retention of ascorbic acid and thiamine would occur after one year's storage. Eighty percent retention at the end of this period was assumed by the authors to be a criterion of change. Table 3 illustrates the information obtained. It is observed that storage temperatures up to approximately 70° F. for periods of 1 year would not produce ascorbic acid losses exceeding 20% for orange juice, lima beans and apricots. In tomato juice, peas, and spinach, losses not exceeding 20% in 1 year could be obtained with storage temperatures up to 80° F. (27° C.). In the case of thiamine retention, storage temperatures up to 85° F. (29.5° C.) for tomato juice and peas and up to 95° F. (35° C.) for orange juice

TABLE 3

Predicted Vitamin Retention Characteristics of Canned Foods

	Ascorbic Acid: Max. Storage temp. for 12 mos. for 80% Retn.	Ascorbic Acid: Max. Storage time at 35° F. for 80% Retn.	Ascorbic Acid: Retn. for 12 mos. Storage at 35° F.	Ascorbic Acid: Retn. for 12 mos. Storage at 100° F.	Thiamine: Max. Storage temp. for 12 mos. for 80% Retn.	Thiamine: Max. Storage time at 35° F. for 80% Retn.	Thiamine: Retn. for 12 mos. Storage at 35° F.	Thiamine: Retn. for 12 mos. Storage at 100° F.
	° F.	Mos.	%	%	° F.	Mos.	%	%
Apricots	68	90	99	0	16	8	72	35
Green Beans	....	....	....	....	28	10	76	8
Lima Beans	67	25	90	63	64	33	92	48
Tomato Juice	84	100	100	63	83	100 +	100	60
Peas	79	45	93	68	88	100 +	100	68
Orange Juice	72	100	100	5	96	100 +	100	78
Spinach	81	62	97	68	....	......	......	....

resulted in losses not exceeding 20%. However, lower temperatures were needed to maintain the same thiamine stability in lima beans, apricots and green beans, namely 64°, 16°, and 28° F. (18°, —9°, and —2° C.) respectively.

Another interesting comparison was made on vitamin stability in the various foods at 35° F. (1.5° C.) to determine if the differences observed at the higher temperatures were maintained at the lower temperature. The number of months storage required at 35° F. to show a significant decline (80% retention) in nutrient content was estimated and the percent retention following 1 year's storage at 35° and 100° F. (1.5° and 38° C.) compared. It is indicated in Table 3 that the differences in stability of foods shown at the high temperature become less marked at the lower temperature as would be expected from the increased stability resulting at lower storage temperatures, (i.e. 0 and 5% ascorbic acid retention in apricots and orange juice respectively after 12 months' storage at 100° F., compared to the 65% retention for the other foods; 99 and 100% retention at 35° F. respectively compared to the 90-100% retention for the other foods). Another observation worthy of note is the apparent reversal of relative stability of ascorbic acid in peas and lima beans at the lower temperature. Although the maximum storage temperature to produce 80% retention of ascorbic acid in 1 year was practically identical for apricots and lima beans, and for orange juice and peas, the stability at 35° F. was almost four times as great for apricots as for lima beans and two times as great for orange juice as peas. In the peas and lima beans, retention of ascorbic acid did not show as marked a temperature relationship as shown for other foods. This may in part be explained by the starchy nature of these two foods and the subsequent formation of interfering substances which reacted as ascorbic acid on storage at elevated temperatures, thus producing apparently greater stability than in other foods.

The possibility of predicting retention of ascorbic acid and thiamine in foods of similar nature to those from which the nomographs were derived is indicated in Table 4. Retention for peaches, tomatoes and grapefruit juice was predicted from data based on apricots, tomato juice and orange juice respectively. It is seen that with the exception of thiamine retention in peaches,[1] satisfactory agreement of the found values with the predicted values was obtained. This comparison is an indication that the nomographs presented may be used for the purpose of predicting nutrient stability in similar foods. Caution should be used in employing these nomographs for such a purpose until more experimental data are available.

TABLE 4

Comparison of Predicted and Found Retention Values for Related Foods (6 months' storage)

	Storage Temperature ° F.	Ascorbic Acid		Thiamine	
		Found % Retn.	Predicted % Retn.	Found % Retn.	Predicted % Retn.
Peaches *(6)*	50	90	97	97	83
	65	84	91	97	74
	80	78	78	92	68
Tomatoes *(6)*	50	96	100	100	100
	65	92	99	95	99
	80	89	92	90	92
Grapefruit Jnice *(6)*	50	92	100	100	100
	65	90	93	98	100
	80	82	82	94	100
Grapefruit Juice *(5)*	70	94	92	....	....

Summary and Conclusions

Based on data obtained on several canned foods for 18 months' storage at three controlled storage temperatures, 70°, 90°, 100° F. (21°, 32°, and 38° C.), nomographs for ascorbic acid and thiamine retention for these foods were derived. These nomographs made it possible to extend the findings in terms of retention of the nutrients to constant and variable temperatures and times outside the range of the study. The type of information which may be obtained in terms of nutrient stability is demonstrated. Findings of other workers at temperatures other than those used to derive the nomographs were compared with predicted values from the nomograph and good agreement observed. The application of this technique to the prediction of the retention of nutrients in foods of like nature to those for which nomographs are given is also discussed.

Acknowledgment

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[1] Although peaches were considered a similar food to apricots, the initial thiamine concentration of peaches was approximately one-half that of apricots *(4)*, whereas the initial thiamine and ascorbic acid content of the other pairs of foods were of the same order of magnitude. This discrepancy may be the explanation for the disagreement in predicted and found thiamine values in peaches.